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NATURAL REVEGETATION OF DEPLETED MOUNTAIN GRAZING LANDS.

PROGRESS REPORT.

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NATURAL REVEGETATION OF DEPLETED MOUNTAIN GRAZING LANDS.

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INTRODUCTION.

Experiments to devise an effective and economic method of increasing the carrying capacity of the grazing lands in the National Forests were started on the Wallowa National Forest in the spring of 1907. The Forest Service and Bureau of Plant Industry, acting in cooperation, continued these experiments through the season of 1908.

The chief aims of the studies are to determine: (1) The relative importance of the forage, by a study of their abundance, distribution, seed habits, and forage value. (2) The dates on which each of the principal plants sends up its flower stalks, and the dates at which it matures its seeds. With this information it should be possible to devise a system of protection to the plants from grazing animals during the period required for seed production. (3) The rate and extent of the revegetation of important forage plants upon overgrazed areas, both under the present range management and upon areas exempt from grazing animals. (4) What plants, under the present grazing system, are succeeding upon depleted range areas and what type of vegetation may eventually predominate. (5) What system of grazing will restore the former productiveness of the range through natural reseeding.

A previous investigation[a] brought out these facts: That the most severely overgrazed areas are bald buttes and glades at elevations of from 1,980 to 2,600 meters (6,500 to 8,500 feet), which were originally covered with mountain bunchgrass (*Festuca viridula*); and that even under the grazing regulations of the Forest Service these ranges are not restocking, because the plants are eaten before their seeds mature. Even where there is a considerable variation of time when the seeds of the different range plants mature, and also a variation within the species according to situation, there is a definite relation between this maturity and the general progress of the season. The flower stalks of mountain bunchgrass, for example, begin to show

[a] Forest Service Circular 158. The Revegetation of Overgrazed Range Areas.

about July 15 and the seeds are usually ripe by August 30, and are then immediately disseminated. This grass is readily eaten by sheep, except for the unpalatable seed stalks, after the seed has dropped, and there is still sufficient grazing season left to consume the forage. The vitality of the seeds of range plants was found to be low, and laboratory tests show that only 8 per cent of bunchgrass seed germinated, and of all the forage seeds tested only 21 per cent. This low vitality was probably due to the cold weather of the latter part of August, when the seeds were in the "milk" or "dough" stage.

The present circular is a progress report of the work begun in 1907 and of the experiments inaugurated in 1908.

PLAN OF INVESTIGATIONS IN 1908.

One of the chief aims was not to change the common grazing practice any more than was absolutely necessary, and thus avoid any needless economic disturbance that might follow if the stock-raising interests were deprived of the use of a large part of the forage crop.

Four main plans of the experiment were: (1) That areas of mountain bunchgrass of convenient size and locality, but not larger than one-fifth of the total area occupied by a band of sheep, were to be selected and closed to grazing from the beginning of the season until the seeds of this grass and of other important species should mature; (2) that the areas and their exact boundaries were to be decided upon by the forest officer in charge, in consultation with the forest supervisor and the stockmen to whom the allotments have been assigned; (3) that, upon notification by the forest officer in charge of the investigations that the seed crop upon each reserved area was mature, the range would be opened to moderate grazing at any time during the remainder of the season by the band of sheep allotted to the range to which the closed area belongs; and (4) that the same area would be closed to sheep for the same period on the following year in order to give the seedlings an opportunity to develop a strong enough root system to withstand trampling, and also to permit a second seed crop to be developed and disseminated if the first year's seeding was unsuccessful.

These experiments were inaugurated in 1908 on three different allotments on the ranges along Bear Creek, in the southern part of the Wallowa National Forest.

CHARACTER OF THE GRAZING LANDS.

There are four types of grazing land, from the valleys to the highest mountains. From the lower to the higher grazing areas in the Wallowa Mountains there is a rugged topography and a wide altitudinal range, and corresponding differences in the type and charac-

ter of the vegetation. As a concrete example, on the lower areas the yellow pine (*Pinus ponderosa*) grows more abundantly than any other tree, and is therefore typical, but with the increase in altitude yellow pine gives way to lodgepole (*Pinus murrayana*), equally characteristic of a somewhat higher elevation. These changes in vegetation are due to differences in controlling physical factors which change with altitude. Since there is this direct relation between plant life and the physical factors which make up its environment, it is evident that modifications in this environment will call forth corresponding modifications in vegetation. This marked relationship arranges the grazing lands in several rather distinct belts or zones. In each of these zones one species, or group of species, makes up a characteristic plant covering, though the characteristic plants of the zones may blend and intermix, especially along their boundary lines.

The distinct belts may be designated as the transition or yellow pine zone (900 to 1,400 meters = 3,000 to 4,500 feet); the Canadian or lodgepole pine zone (1,400 to 2,100 meters = 4,500 to 6,800 feet); the Hudsonian or white-bark pine zone (2,000 to 2,600 meters = 6,500 to 8,500 feet); and the arctic-alpine or timberless zone (2,450 meters and above = 8,000 feet and above).

The altitudinal limits of the zones, as stated, are only approximate, because altitude is not the only factor that controls the distribution of plants, for it affects plant life only through its effects on the most potent physical influences—moisture and temperature. Slope and exposure play an important part in influencing distribution and vegetation, and the north and east slopes are usually more cool and moist than southern and western ones.

TRANSITION OR YELLOW PINE ZONE.

The transition or yellow pine zone, the lowest of the four zones of vegetation, is the most limited in extent, with the exception of the arctic-alpine belt, which apparently affords no grazing. This region is locally called the yellow pine belt. (See fig. 1.) Yellow pine usually does not grow in pure stands, but is generally associated with Douglas fir (*Pseudotsuga taxifolia*) and western larch (*Larix occidentalis*), all of which have an open character of growth that usually permits a fair ground covering of herbaceous vegetation. The most abundant herbaceous plant in the timber is pine grass (*Calamagrostis suksdorfii*) (fig. 1). On the lower areas timber gives way to herbaceous vegetation in which bunchgrass predominates. The most common species are big bunchgrass (*Agropyron spicatum*), little bluegrass (*Poa sandbergii*), and blue bunchgrass (*Festuca arizonica*), named in their order of abundance.

As early as April 1 some of the south slopes on the lowest areas in this belt are clear of snow, and at times during the month conditions are favorable to growth, though April has frequent cold waves and there are heavy frosts almost every night, so that germination and growth make little or no headway until May.

FIG. 1.—A typical yellow pine forest after the pine grass has been moderately grazed.

CANADIAN OR LODGEPOLE PINE ZONE.

The Canadian or lodgepole pine zone has an average altitude of 1,400 to 2,100 meters (4,500 to 6,800 feet), though the zone may extend 150 meters (500 feet) below the minimum height on north slopes and about this same distance above the maximum on south exposures.

This zone is considerably greater in extent than the transition belt and it is probably the most heavily timbered of any of the zones, in spite of the fact that fires have been unusually destructive and there are many burns that are not yet reforested. Lodgepole pine is the predominant and most typical tree. In some places, more particularly on the moister and cooler north and east slopes, lodgepole does not grow in pure stand, but there is an intermixture of western larch and lowland fir. On the drier burned-over areas lodgepole repro-

duction usually follows a fire in a few years. But prior to this permanent type there follows, as a forerunner, after burning, an intermediate or transitory growth of "weeds," of which the fireweed (*Epilobium spicatum*), a valuable forage for sheep, and *Anaphalis margaritacea* are the most common. Grass land and forest are extremely antagonistic in this belt. Where tree reproduction is hindered, either by the absence of seeds, by the recurrence of fires, or by the lack of the proper physical conditions, open, grassy "parks" have developed, though they are rather exceptional in this zone and their areas are small. In many situations, however, lodgepole pine growth is so dense that there is a striking absence of herbaceous plants, such as characterize the yellow pine belt. In their stead are a number of shade-enduring, woody plants, locally called "chaparral" because of their characteristic dense habit. Most of them are browsed ravenously by sheep, and they furnish the bulk of the forage in this zone.

Growth barely begins in this zone by May 20, or twenty days later than in the zone below, and then it is confined to the lower, most favorable situations. There are comparatively few plants in this belt which do not grow to some extent in the contiguous zones above and below.

HUDSONIAN OR WHITE-BARK PINE ZONE.

The Hudsonian or white-bark pine zone lies immediately above the Canadian, at an approximate altitude of 2,000 to 2,600 meters (6,500 to 8,500 feet), and includes all of the high range except the crests and peaks of those mountains which extend beyond the uppermost limits of tree growth. This belt, though not suitable for early grazing, will carry as much stock as both of the lower zones together, and in extent is probably nearly equal to both.

The most characteristic tree in this region is white-bark pine (*Pinus albicaulis*), the limits of which are more sharply marked than those of any other common tree in the forest. It does not grow below 2,000 meters (6,500 feet), the approximate altitude at which this zone begins, and is found throughout the belt to the normal timber line. Subalpine fir (*Abies lasiocarpa*) grows here more abundantly than white-bark pine, but because of its wider range it is not as truly characteristic of the zone. Engelmann spruce (*Picea engelmanni*) is also common, but since it grows only in the moister and cooler situations it is not so widely distributed.

Extensive open meadows and scattered woodlands are the most striking features of the Hudsonian zone. (See fig. 2.) The timber usually grows in restricted dense clumps. The comparative absence of timber in this belt is possibly due in part to the inability of the

seedlings successfully to withstand the extreme temperatures of the first winter's exposure, but the primary cause may be the occupation of the soil by perennial grasses.

In spite of the fact that this zone has been severely overgrazed, many glade areas still have a luxuriant growth of mountain bunchgrass (*Festuca viridula*), a plant of preeminent forage value. A number of perennial grasses are associated with mountain bunchgrass and add considerably to the character of the plant growth. Also there are several weed-like annual and perennial species which are important as affecting the general character of the vegetation.

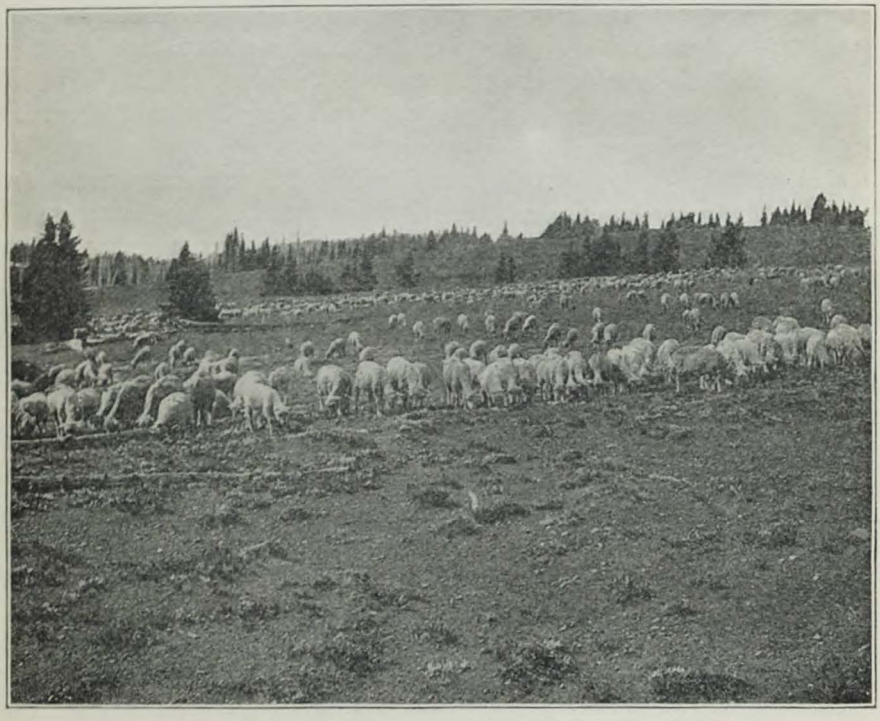

FIG. 2.—A flat overgrazed ridge in the Hudsonian zone, showing the open character of the country.

New growth began in this zone on June 25, at which time only a few of the south and west slopes were free from snow. A week later, however, most of the snow was gone and only parts of the larger snowdrifts remained.

ARCTIC-ALPINE OR TIMBERLESS ZONE.

There is no grazing in the arctic-alpine or timberless zone, which constitutes the fourth distinct type of vegetation. This zone marks conditions that prevent the growth of trees. Such conditions exist only on the highest crests and peaks, and consequently the areas are

extremely limited in extent. The plant covering is sparse, and few of the species of this zone grow in the others. These species are capable of withstanding unusually low temperatures and even heavy frosts during the growing period, and they complete their cycle of development in a comparatively short time. Among the most characteristic and abundant plants of this group may be mentioned *Eriogonum piperi*, *Draba aureola*, *Hoorebekia lyallii*, *Hulsea nana*, and alpine bunchgrass (*Festuca brachyphylla*), and of these only the last has any grazing value. Except for a small portion of one of these areas, which dips into the Canadian life zone at an altitude of 1,700 meters (5,500 feet), they are entirely confined to the Hudsonian zone, the true home of mountain bunchgrass.

OBSERVATIONS IN 1908.

SEASONAL PROGRESS OF THE VEGETATION.

The time at which the vegetation is awakened to growth in the different zones is widely varied. In the Hudsonian zone growth began in general thirty-five days later than in the Canadian belt, which is immediately below, and fifty-five days later than in the transition zone.

There are three distinct seasonal periods in the Hudsonian zone—spring or growth-resumption period, June 25 to July 15; summer or main growing period, July 15 to August 15; and autumn or maturing period August 15 to September 15. The dates do not mark a definite limit to the seasons, but simply indicate in a general way the growing periods.

The spring period is marked by the appearance of some of the earliest species and the general germination of both annual and perennial plants; the summer period is characterized by the growth and development of the vegetation; and the third period comes gradually and continues until about September 15, when most of the vegetation, especially that valuable for grazing, has matured, and, for the most part, disseminated its seeds.

Spring beauty (*Claytonia lanceolata*) is first to push through the cold, saturated soil. A couple of days later it is abundant in some situations, and usually it follows closely as the snow recedes. Following spring beauty the first plants to unfold their buds, during the first week in July, are three inconspicuous annuals, Douglas knotweed (*Polygonum douglasii*), *Gayophytum ramosissimum*, and *Collinsia tenella*, all useless as grazing plants. They are typical of lower elevations and have come in on denuded mountain bunchgrass areas, to which they are closely restricted. After these, the brownish tints of the dead leaves and flower stalks of the season

before are effectively enlivened by the vigorous green of two sedges, elk grass (*Carex geyeri*) and sickle sedge (*Carex umbellata brevirostris*). Unlike most sedges, they are restricted to the drier situations, and are fully two weeks earlier than most of the others. Elk grass is especially abundant on certain slopes, but it is grazed with little relish; and sickle sedge is hardly touched by stock. During the earlier part of the second week in July there appear two moisture-loving buttercups (*Ranunculus glaberrimus* and *R. suksdorfii*). They are conspicuous because of their density and their numerous yellow flowers, which last, however, only a few days.

At this point there is a slight decline in the general flowering of the vegetation which is not interrupted until July 15, when some of the grasses begin to put forth their flower stalks and thus mark the beginning of the summer or main growing season. The first to flower are little bluegrass (*Poa sandbergii*), mountain bluegrass (*Melica bella* and *M. spectabilis*), and June grass (*Koeleria cristata*), all common at lower elevations. These are closely followed by a large number of species, of which the most noticeable are mountain bunchgrass (*Festuca viridula*), northern wild rye (*Elymus borealis*), smooth wild rye (*Elymus glaucus*), and brome grass (*Bromus marginatus*). Of this list, mountain bunchgrass is by far the most generally distributed and grows in greatest abundance, though all are conspicuous throughout the season. Again, about July 20, a set of plants of somewhat higher water requirements than these grasses put forth their flower stalks; among them are mountain timothy (*Phleum alpinum*), reed grass (*Cinna latifolia*), tall meadow grass (*Panicularia nervata*), and two sedges (*Carex hoodii* and *C. oblata*), all of which form a turf, and in certain situations any one of them may form the controlling species. During the last week of July, when the grazing season begins in this zone, and extending well into August, the white flowers of *Pedicularis bracteosa* are conspicuous, and in the drier situations the blue flowers of *Veronica serpyllifolia* are closely associated.

The physical conditions of the summer period differ markedly from those of the spring period; the mean daily temperature is about 7 degrees higher; the evaporation is approximately 3.5 per cent greater; and the soil water content about 6 per cent lower.

In the first week in August and extending over a considerable period, several new floral types appear, both in the marshy and in the dry situations. These contribute largely to the late summer and fall forage supply. In the marshy places the most valuable grazing plants are butterweed (*Senecio triangularis*), conspicuous because of its yellow heads and ray flowers and tall leafy stem, rather than for its abundance; the highly relished mountain onion (*Allium validum*),

with its restricted dense growth and tall leafless stalks terminating in attractive pink flowers; and the broad-leafed false hellebore (*Veratrum viride*), which is little grazed until nipped by frosts. On the drier areas the most conspicuous of the valuable grazing plants are red huckleberry (*Vaccinium scoparium*), Jacob's ladder (*Polemonium humile*), *Erigeron membranaceum*, blue foxglove (*Pentstemon procerus*), and wild celery (*Ligusticum oreganum*). The huckleberry and Jacob's ladder are both shade-enduring plants and are closely restricted to the timbered areas, and the former, usually in association with a low-branching shrub, mountain heather (*Phyllodoce empetriformis*), reaches the normal timber line. The other three species, of which wild celery is the most widely distributed and the most palatable, occupy the exposed areas and usually grow in scattered stands.

During the second week in August, mountain dandelion (*Agoseris glauca*), larkspur (*Delphinium glaucum*), and a low-branching annual (*Monolepis nuttalliana*), become, vegetatively and florally, of primary importance. Because of their long blooming period (extending in some cases into September) they add considerably to the autumnal floral character of these areas. In grazing value, mountain dandelion easily ranks first, the larkspur, although presumably poisonous when taken in quantity, is eaten to some extent, and the annual is apparently of no value for forage.

The middle of August marks the completion of the main growing period and the beginning of the autumnal or ripening season. Among the conspicuous plants of grazing value that mature about this time are two species of wild onion (*Allium platyphyllum* and *A. collinum*), wild buckwheat (*Polygonum phytolaccaefolium*), elk grass (*Carex geyeri*), and small bluegrass (*Poa sandbergii*). The seeds of these plants are ripened before the last week of August. Important forage plants that have matured their seeds by September 1, named in their order of ripening, are red huckleberry (*Vaccinium scoparium*), western needle grass (*Stipa occidentalis*), northern wild rye (*Elymus borealis*), wood rush (*Juncoides glabratum*), and mountain bunchgrass (*Festuca viridula*). On some of the protected north exposures the seeds of mountain bunchgrass are not mature until the first week in September, but in most situations it is mature by the last of August.

By September 1 the vegetation of the Hudsonian zone has taken on a general brownish cast indicative of complete maturity. With frequent fall rains and a lowered temperature physical conditions have considerably changed from those of the summer period. The mean temperature [a] at this time is 6 degrees lower than in the

[a] Temperature records were obtained by daily readings from maximum and minimum thermometers, Fahrenheit scale, taken in a typical station in this zone.

summer season; the evaporation[a] averages 4 per cent lower; and the soil moisture[b] shows an increase of 5 per cent; thus this period corresponds somewhat to the spring period.

SEED PRODUCTION.

PRODUCTION OF FLOWER STALKS.

The wide contrast in the physical conditions of this region naturally stimulates an irregular awakening to growth, and causes the flower stalks to be sent forth at widely different periods. The effect of altitude alone, other things remaining the same, retards the production of the flower stalks from seven to ten days per 300 meters (1,000 feet). The effect of the different slopes and exposures, even at approximately the same altitudes, is also very pronounced.

Varied local conditions and their effect on the progress of vegetation are shown, for example, in the case of a north slope in the Hudsonian zone with an altitude, at the crest, of 2,390 meters (7,855 feet), and an incline of 15° to 18°. North slopes at this altitude are the last to recover from winter, and vegetation is, in general, later than on any of the other exposures. With a succession of warm, sunny days the snow began first to recede on the crest, then to disappear on the slope, and finally to leave the base. As the snow disappeared, almost immediate activity of growth followed. The crest was characterized by a sparse green covering when growth had barely begun on the slope; and a similar relationship existed between the slope and the base. In the early part of the season there are marked differences between the amounts of soil moisture present at the crest, slope, and base; the average percentages were 23.2 per cent, 27.6 per cent, and 39.9 per cent, respectively. As the season advanced, however, the moisture conditions gradually became equalized, and in the latter part of the growing season there were no appreciable differences.

The time at which the flower stalks were produced corresponded to the time at which growth started. On the crest the flower stalks appeared from three to six days earlier than upon the slope, and from seven to nine days in advance of those on the base, yet as a result of the equalization of the moisture conditions in the soil, with the advance in the season, the vegetation as a whole presented a strikingly uniform

[a] The rate of evaporation was determined by means of the "Piche" standardized evaporimeter. While it is recognized that this instrument may not give entirely accurate quantitative measurements, it furnishes an invaluable index to the relative humidity and corresponding transpiration demand on the vegetation in the different zones.

[b] Soil moisture determinations were made every ten days through the season in the station and in the immediate vicinity. For technique, see Clements, Research Methods in Ecology, 1905.

appearance toward the end of the growing period; and though the ripening of seed began somewhat later at the base than upon the crest, the delay was not nearly so pronounced as was the beginning of growth.

Yet the variation in the time during which the flower stalks are produced by the different species, and by individuals of a single species in a given locality, is not always due to their direct response to the physical conditions, but in some cases it is the result of too frequent cropping and excessive grazing. In 1907 it was found that these variations within species applied almost exclusively to the most palatable and highly relished plants, and it was particularly noticeable in the case of mountain bunchgrass. Two mountain bunchgrass areas, overgrazed in different degrees, were therefore selected and closed to sheep by substantial fences before the crop had been removed. In the season of 1907 the period during which mountain bunchgrass sent up the flower stalks was forty-one days, beginning July 10 and continuing until August 20. Yet in 1908 in the protected areas the first flower stalks shot up on July 17, and none were produced after August 15. This gives a total of thirty days, or a decrease of 26.8 per cent in 1908 as compared with the preceding season. Not only did the flower stalks on these areas shoot up more uniformly in 1908, but they were produced much more abundantly, and the leaves of the plants, though not entirely recovered from the lowered vitality, showed greater vigor.

Table 1 shows the time during which the various important grazing plants put forth their flower stalks. All these plants were recorded within the boundaries of mountain bunchgrass (fig. 3), the preeminently important grazing plant within the approximate limits of 1,980 to 2,600 meters (5,600 to 8,500 feet). They are arranged in the order of their grazing value.

The earliest appearance of flower stalks of mountain bunchgrass in 1908 was July 3, when a few scattering stalks appeared on warm south and west slopes. During the following ten days they became progressively abundant until August 5. After that the production of the flowers progressively diminished until August 15, when practically no more were produced. The earliest flower-stalk production of the various species was June 1. The latest, as yarrow (*Achillea millefolium lanulosa*) and pine grass (*Calamagrostis suksdorfii*), were produced until inclement weather stopped their activity. The time of maximum production of all species was from July 15 to August 10. About 32 per cent of the average plants listed depend upon insects for the transference of their pollen, and 68 per cent are wind pollinated. In the latter group are included all the grasses, sedges, and rushes.

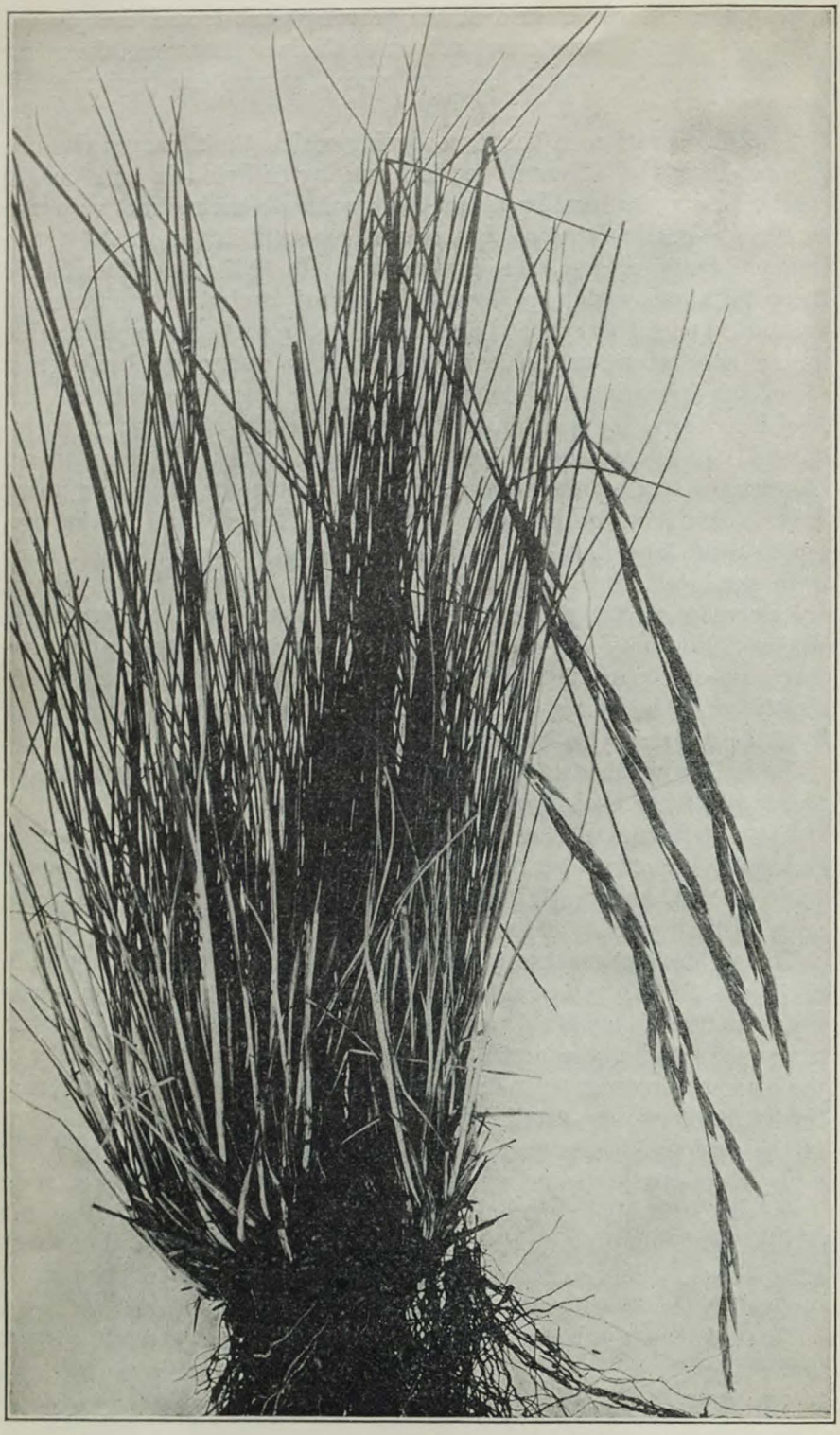

FIG. 3.—Mountain bunchgrass (*Festuca viridula*), showing a part of the dense, much-branched root system, the flower stalks and inflorescence, and the tufted or bunched habit of growth. Natural size.

TABLE 1.—*The time of flower-stalk production and seed maturity, and the fertility of the subsequent seed crop of the high-range grazing plants.*

Name of plant.		Flower stalks, when produced.		Seeds, when matured.		Seed fertility (germination).	
Local.	Scientific.	1907.	1908.	1907.	1908.	1907.	1908.
						Per ct.	*Per ct.*
Mountain bunchgrass	Festuca viridula	July 10–Aug. 20	July 3–Aug. 15	Aug. 18–Sept. 5	Aug. 15–Sept. 5	8.0	[a] 15.5
Small bluegrass	Poa sandbergii	July 10–Aug 1	July 10–Aug. 10	Aug. 20–Sept. 5	July 15–Aug. 20	9.5	6.0
Short-awned brome-grass	Bromus marginatus	July 25–Aug. 10	July 25–Aug. 10	Aug. 15–Sept. 10	Aug. 15–Sept. 15	38.0	47.0
Tufted hair grass	Deschampsia caespitosa	July 25–Aug. 10	July 25–Aug. 15	Sept. 1–Sept 10	Sept. 5–Sept. 20	22.5	29.0
Mountain bluegrass	Melica spectabilis	July 20–Aug. 10	July 15–Aug. 15	Aug. 25[b]	Aug. 15–Sept. 15	0	4.0
Big bunchgrass	Agropyron spicatum	Aug. 1–Aug. 20	Aug. 10–Aug. 30	Sept. 1	Aug. 20	16.0	.30
Blue bunchgrass	Festuca arizonica	June 10–July 25	June 5–July 15	Aug. 15–Aug. 30	Aug. 10	4.0	11.5
Mountain June grass	Koeleria cristata	July 10–July 25	July 10–July 25	Aug. 20–Sept. 10	Aug. 15–Sept 10	16.0	14.0
Mountain bluegrass	Melica bella	July 20–Aug. 10	July 10–Aug. 15	Aug. 25	Aug. 20–Sept 10	0	2.0
Red bunchgrass	Agropyron flexuosum	Aug. 1–Aug. 20	Aug. 10–Aug. 31	[c]	Sept. 10	0	11.5
Western wheat grass	Agropyron biflorum	Aug. 1–Aug. 20	Aug. 5–Aug. 20	[c]	Aug. 20–Sept. 30	78.0	96.0
Yarrow	Achillea millefolium lanulosa	June 10–Aug. 25	June 10–Sept. 10	Sept. 1	Aug. 20	[d]	16.5
Wild parsnip	Ligusticum oreganum	July 20–Aug. 5	July 12–Aug. 5	Aug. 25	Aug. 20–Sept. 10	2.0	6.0
	Trisetum spicatum	July 15–Aug. 1	July 10–Aug 5	Sept. 5–Sept. 10	[c]	11.0	0
Smooth wild rye	Elymus glaucus	July 15–Aug. 1	July 10–Aug. 5	[c]	Aug. 25	0	24.5
Butterweed	Senecio triangularis	Aug. 1–Aug. 20	Aug. 1–Aug. 25	Sept. 1–Sept. 10	Aug. 25	[d]	18.0
Cone flower	Rudbeckia occidentalis	July 10–Aug. 15	July 10–Aug. 20	Aug. 25	Aug. 25–Sept. 20	16.0	24.5
Wild buckwheat	Polygonum phytolaccaefolium	July 20–Aug. 5	July 15–July 31	[c]	Aug. 1–Aug. 20	[d]	3.0
Northern wild rye	Elymus borealis	July 5–July 25	July 5–July 30	Aug. 15–Aug. 30	Aug. 1–Aug. 20	11.3	21.5
Pine grass	Calamagrostis suksdorfii	July 20–Sept. 10	Aug. 1–Sept. 20	Aug. 15	Aug. 10–Sept. 10	58.2	76.0
Mountain timothy	Phleum alpinum	July 15–July 25	July 15–Aug. 1	Aug. 15	Aug. 20–Sept. 15	59.0	76.5
Western needle grass	Stipa occidentalis	July 20–Aug. 5	July 15–Aug. 10	Aug. 15–Aug. 25	Aug. 10–Aug. 25	19.0	27.3
Horsemint	Lophanthus urticifolius	July 10–Aug. 20	July 8–Aug. 20	Aug. 25	Sept. 1–Sept. 15	[d]	16.0
Wood rush	Juncoides glabratum	July 25–Aug. 10	July 25–Aug. 15	Aug. 17–Sept. 1	Aug. 15–Aug. 30	[d]	6.0
Nuttall willow	Salix nuttallii	June 1–June 20	June 5–June 15	[c]	[c]	[d]	[d]
Blue huckleberry	Vaccinium membranaceum	June 5–June 25	June 10–July 1	Aug. 1–Sept. 10	Aug. 5–Sept. 5	[d]	17.0
Mountain dandelion	Agoseris glauca	July 20–Aug. 15	Aug. 10–Sept. 5	Aug. 10	Aug. 5–Aug. 25	11.5	15.5
Tall bluegrass	Poa brachyglossa	June 1–July 5	June 1–July 10	Aug. 5–Aug. 20	Aug. 1–Aug. 20	16.5	[d]
Black hair grass	Deschampsia atropurpuria	July 10–Aug. 15	July 5–Aug. 25	[c]	Sept. 1–Sept. 15	[d]	20.0
Mountain onion	Allium validum	July 1–Aug. 5	July 5–Aug. 15	Aug. 25	Aug. 25–Sept. 10	[d]	36.0
Red huckleberry	Vaccinium scoparium	Not recorded	June 25–July 10	Not recorded	July 25–Aug. 15	[d]	22.0
Little needle grass	Stipa minor	July 25–Aug. 10	July 20–Aug. 15	Aug. 10–Aug. 31	Aug. 20–Sept. 10	26.0	39.0
Wild onion	Allium platyphyllum	June 1–June 25	June 5–July 1	Aug. 1–Aug. 10	July 10–July 30	[d]	26.0
Wild onion	Allium collinum	June 1–June 25	June 1–June 25	Aug. 1–Aug. 10	July 10–July 30	[d]	0
Tall swamp grass	Carex exsiccata	June 20–July 15	June 20–July 10	Aug. 25–Sept. 5	Sept. 1–Sept. 15	0	6.5

[a] In the case of mountain bunchgrass the best, not the average, of the germination tests is given because of several failures in some of the sets tested.
[b] A blank following the date of seed maturity indicates that only a few seeds matured at the time specified, and the remainder of the seed crop never reached full development.
[c] No seeds reached full maturity.
[d] No germination test was made.

TABLE 1.—*The time of flower-stalk production and seed maturity, and the fertility of the subsequent seed crop of the high-range grazing plants*—Cont'd.

Name of plant.		Fower stalks, when produced.		Seeds, when matured.		Seed fertility (germination).	
Local.	Scientific.	1907.	1908.	1907.	1908.	1907.	1908.
						Per ct.	*Per ct.*
False hellebore	Veratrum viride	Aug. 5–Sept. 1	Aug. 5–Aug. 31	Sept. 1	Sept. 1	(a)	(a)
Alpine redtop	Agrostis rossae	July 15–Aug. 15	July 12–Aug. 5	Aug. 25–Sept. 5	Aug. 20–Sept. 10	29.0	38.5
Elk grass	Carex geyeri	June 20–July 15	June 20–July 10	Aug. 1–Aug. 15	July 15–Aug. 5	6.0	26.0
Jacob's ladder	Polemonium humile	Not recorded	July 10–Aug. 30	Not recorded	Aug. 20–Sept. 10	(a)	41.5
Reed grass	Cinna latifolia	July 5–Aug. 5	July 10–Aug. 15	Aug. 25–Sept. 10	Sept. 1–Sept. 20	79.0	97.0
Wire sedge	Carex hoodii	July 1–July 20	July 5–July 20	Aug. 5–Aug. 20	Aug. 5–Aug. 25	10.0	(a)
Tall meadow grass	Panicularia nervata	July 15–July 30	July 10–July 31	Not recorded	Aug. 25–Sept. 10	(a)	85.0
Slender hair grass	Deschampsia elongata	July 15–Aug. 1	July 20–July 31	Sept. 1–Sept. 10	Aug. 25–Sept. 10	24.0	33.0
Rush	Juncus confusus	June 20–July 15	June 20–July 15	Aug. 10–Aug. 25	Aug. 15–Aug. 30	(a)	32.0
White foxtail	Sitanion velutinum	June 25–Aug. 1	June 20–Aug. 5	Aug. 20	Aug. 20–Sept. 15	43.0	77.0
Rush	Juncus mertensianus	July 1–July 20	June 25–July 20	Aug. 20–Sept. 10	Aug. 15–Sept. 10	(a)	(a)
Rush	Juncus orthophyllus	July 1–July 20	June 25–July 15	Aug. 15–Sept. 10	Aug. 15–Sept. 15	0	17.0

[a] No germination test was made.

PERIOD OF SEED MATURITY.

Although the times of seed maturity are related in some degree to the fluctuations in flower-stalk production, they are not nearly so irregular as the times of putting forth the flower stalks. This seems to be in direct relation to the physical conditions, which are varied in the early part of the growing season, especially with respect to soil moisture, but become more constant with the approach of autumn. The average time required for the majority of the species to mature their seeds was twenty days, which is 33 per cent less time than was required for flower-stalk production. The equalization, then, in the physical condition of the soil with the advance in season explains, in part at least, why the seed crop is ripened comparatively evenly and quickly.

The ripening period in 1908, as compared with the preceding season, was fully five days earlier. Some of the figures in Table 1 might lead to the inference that the seeds were matured more slowly in 1908 than in 1907. This was not the case, however, and the apparent discrepancy can be explained by the fact that in 1907 weather conditions became so adverse after September 10 that the seeds which had not matured at that time were destroyed. In the season of 1908 conditions continued favorable to seed maturity until September 20, and consequently the seeds continued ripening and practically all matured.

In 1908 the seeds of mountain bunchgrass began to mature on August 15, and by August 27 fully two-thirds of the seed crop had ripened. (See fig. 4.) After September 5 practically no immature seeds could be found, even on the cold north slopes in the higher altitudinal limits of this species. In the case of the secondary grazing plants, almost without exception those of greater forage value had matured all their seeds by September 10.

The seeds of most of these species are disseminated almost immediately upon maturity. The two principal means of distribution are dissemination by wind and by attachment to animals, or in the case of fleshy-fruited seeds, by passage through the digestive tract. As would naturally be expected in a region characterized by strong prevailing winds, the majority of the species depend upon seed dissemination by this means. About 90 per cent of the species listed in Table 1 are wind-distributed, and of these 20 per cent have highly specialized contrivances, such as a plumed pappus or feathery appendage (as in the dandelion) or wings, to facilitate a wide distribution. The remaining 10 per cent depend wholly or in part upon animals as a medium of distribution, and among these are the two species of huckleberry.

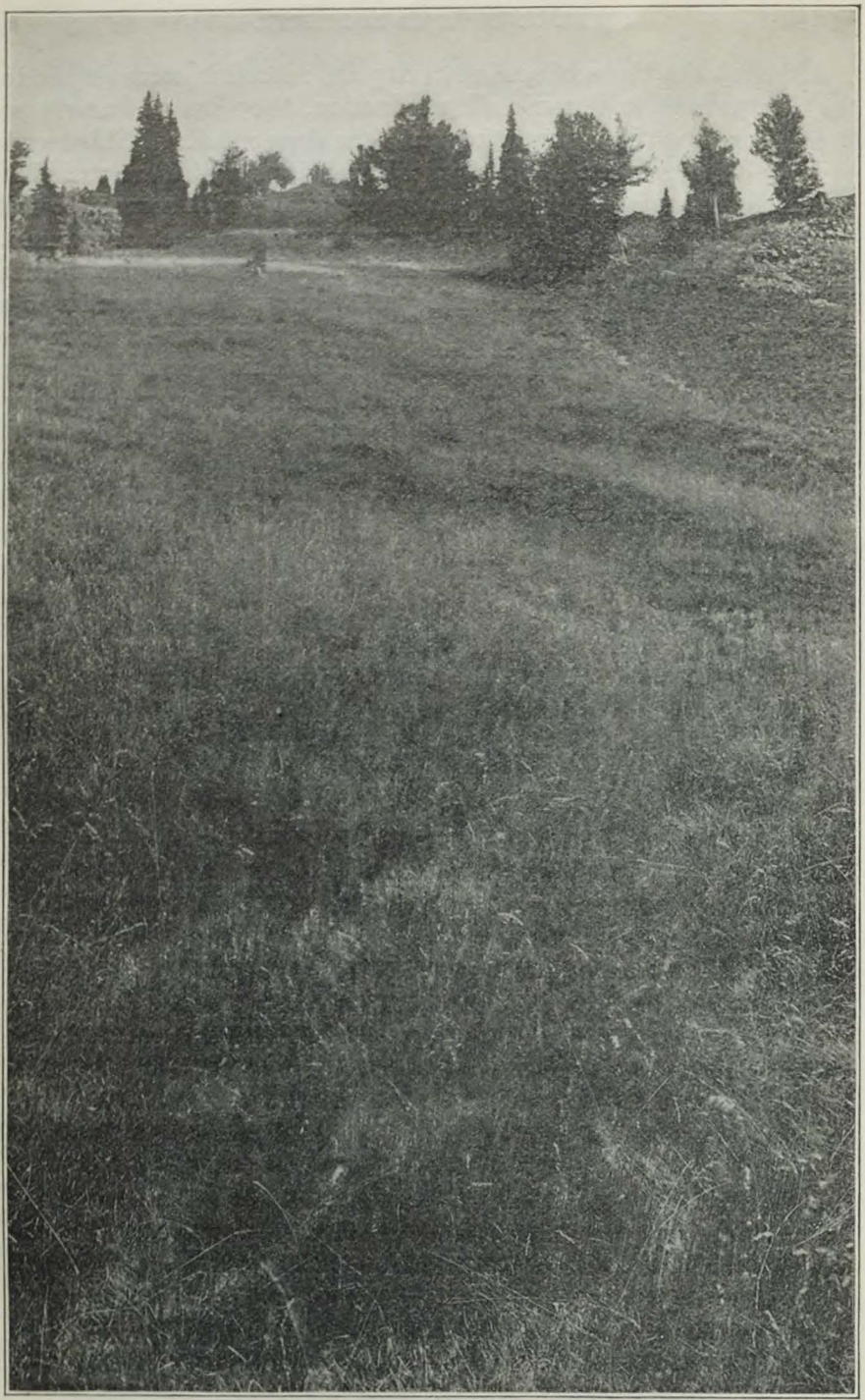

FIG. 4.—A maximum stand of mountain bunchgrass on a west slope on Sturgill range as it appears immediately after seed maturity, before the range has been grazed. Photographed September 2, 1908.

[Cir. 169]

SEED GERMINATION.

On overgrazed ranges there is usually only a very limited stand of the first-class forage plants, and for this reason it is important to know something of the vitality of the resulting seed crop. To ascertain the possibilities of regeneration it is of paramount importance, first, to determine the germination per cent, under favorable conditions, of the seeds of predominant forage plants; second, to study the natural conditions under which they must struggle; and third, to ascertain what species are succeeding and what is the density of the resultant seedling stand.

VITALITY OF THE SEEDS.

During each autumn of the two years of investigation mature seeds of the leading range plants were collected and germination tests, under controlled conditions, were later made in the seed-testing laboratory of the United States Department of Agriculture. Table 1 shows the results, in the per cent of germination, of the tests for the two seasons. With the exception of the mountain bunchgrass the figures are averages of all the determinations.

It will be observed from the table that the vitality of the seeds in 1907 was low as compared with those of 1908. In 1907 no seeds matured in certain situations, and even in the more favorable localities only a fair seed crop was obtained, because some of the more tender species, owing to the unusually low temperature, became air-cured prior to maturing their seeds. In such instances no germination tests were attempted, which explains some of the blank spaces in the table of the first year's record.

CONDITIONS ON THE RANGE DURING THE GERMINATION PERIOD.

Even when a heavy seed crop, with extraordinary power of germination, is scattered over the ground, succession may not be assured. In the spring of 1908, as in 1907, little of the ground on the main high range was free of snow until July 1, and even then portions of the largest snowdrifts remained. But by that time in most situations germination had really started on the mountain bunchgrass ranges, and during the following two weeks the process was completed. During the period from July 1 to 15 the mean air temperature was 50.3° F., and from July 10 to 15 the mean was 56.2°. The mean minimum temperature during these fifteen days was 36.2°. On five nights, all but one of which came before July 10, the temperature dropped below freezing and the lowest temperature was 29.6°. The average temperature at the surface of the ground was 35.4°, and the average soil temperature, taken at a depth of 2.5 cm. (1 inch),

below which depth little or no seed will be found, was 34.2°, and never below freezing during this period. The five nights on which the temperature dropped below freezing were followed by warm days, and consequently the soil temperature was not materially lowered. Germination and growth followed immediately as the snow receded, at which time the moisture condition of the soil was near the point of saturation. For example, the average of three determinations of soil humidity, taken on July 3, at a depth of 2 decimeters (8 inches), gave 57.3 per cent. This amount grew rapidly less from day to day and by July 15 determinations at the same depth averaged 29.6 per cent. The basaltic type of soil, characteristic of this region, is extremely friable and porous, and the superficial layer dries out rapidly to a depth of about 2 inches. As early as July 15 this surface soil was in an air-dry condition in many situations, in which state it remained until July 20, when 0.46 inch of rain fell. Between July 15 and 20 many young seedlings died in some of the driest and most exposed situations. During the first three days the seedlings wilted down in the hottest part of each day, but as the temperature dropped in the evening and the light became less intense they revived. Finally, however, with a repetition in these conditions and with the increasing dryness in the soil, coupled with already lowered vitality, the plants failed to recover, and many succumbed from lack of water. The roots of the seedlings at this time had not penetrated the soil, on the average, more than 2 inches. The soil water content to that depth during this dry period varied from only 4.1 to 9.8 per cent, with an average of 8.4 per cent. Where soil humidity was below 8 per cent very few seedlings lived.

ESTABLISHMENT OF SEEDLINGS ON THE OPEN RANGE.

The areas used in studies of regeneration in 1908 were the same as those in the preceding year. In order that the figures of the germination tests in the laboratory might be comparable to natural conditions, the seeds used in these tests were collected, so far as possible, when the regeneration study was made. The character of the vegetation on the areas studied is here restated from Circular 158:[a]

> Upon the areas selected there are two distinct types of herbaceous vegetation, one of which regenerates much more abundantly than the other. While these types intermix to a considerable extent in certain situations, as a general rule they present well-marked plant formations. For convenience they may be distinguished as follows:
>
> 1. *Constant or perennial vegetation.*—Those plants which continue to grow from year to year and which are more or less in evidence through the season.
>
> 2. *Temporary or annual vegetation.*—Those plants which spring up from seeds each year, flourish but a few weeks, ripen their seeds, and disappear.

[a] Germination of seeds, p. 16.

In the group of constant or perennial vegetation are included all the important grasses and, almost without exception, the other valuable forage plants of the region. It is this type which furnishes the summer, fall, and winter forage. The temporary or annual forage, on the other hand, is composed of very few valuable range plants. The plants of this group are grazed to a limited extent in the spring, when they are succulent and tender, but in most situations they bloom, mature, and disperse their seeds, wither and disappear, before the stock has access to them. The seed habits of this group of annual plants, as compared with those of the other type, are exceptionally strong. The seedlings are particularly prevalent over the areas where the original vegetation, which was largely composed of the constant or perennial type, has recently been destroyed, and the fact that the annual plants which propagate solely by seeds often completely cover such areas illustrates their prolific seed habits.

Table 2 shows the seedling reproduction of the perennial forage plants. Owing to the abundance of the annual seedlings and the limited supply of forage which they afford, their actual density of stand was not definitely ascertained, as in the case of the perennial seedlings, but was only noted in a general way. The information upon which Table 2 is based was secured before the areas were grazed.

It is apparent that the forage plants on the open range are reproducing sparingly. As in 1907, there was in 1908 a wide variation in the density of stands in the different situations. The growth is densest on moist, partially or wholly denuded areas, such as bed ground and depleted meadows, where the soil catches the seeds that are later worked beneath the surface by the trampling of stock. These areas are well supplied with moisture throughout the summer. For example, the most abundant perennial seedlings were on a denuded bed ground on the Sturgill range; an average count of 17 square meters gave 23.6 seedlings per meter, or 10.6 more seedlings per unit area than in any other situation. On this area the minimum soil water content during the driest part of the season was 21.2 per cent, as compared with 5.4 per cent on the drier situation observed, while the average soil water content during the entire growing season was 34.7. The next highest number of seedlings, 13 per unit area, was on the base of a south slope, which ranked next in soil humidity. This is a rather flat meadow, also on Sturgill range. The average soil water content during the summer was 29.6 and the minimum 16.4 per cent.

Where the soil humidity dropped to 6 per cent and below, the seedlings were largely destroyed by lack of moisture. A careful analysis of the identity of the various seedlings confirms the conclusions of 1907, (1) that the plants of highest forage value, including mountain bunchgrass, are not reproducing abundantly by seeds, and (2) that the secondary type of range plants, particularly the sedges, which are grazed only to a limited extent, are succeeding rapidly under the grazing system heretofore followed.

TABLE 2.—*Seedling reproduction of perennial forage plants on mountain-range areas.*

Date of observations.	Locality.	Vegetation.								
		Most characteristic species.	Per cent of ground covered.	Character of soil.	Per cent soil-water content.		Slope and aspect.	Number of unit areas counted.	Total number of seedlings.	Average number of seedlings per square meter.
					Minimum.	Average.				
	Standley range.									
July 20	Basin east of station 4.	Elk grass (*Carex geyeri*), sickle sedge (*C. umbellata brevirostris*), and short-awned brome grass (*Bromus marginatus*).	60	Clayey loam	10.8	17.3	10–20° E.	16	69	4.3
July 20 and 21	Ridge east of station 4.	Alpine redtop (*Agrostis rossae*), *Carex deflexa*, and little needle grass (*Stipa minor*).	12	Gravelly clay loam	12.0	29.6	1° W.	22	286	13.0
July 22 and 23	South of station 4	Mountain bunchgrass (*Festuca viridula*), mountain bluegrass (*Melica bella*), and *Trisetum spicatum*.	20	Clay loam	5.9	24.0	5° W.	26	130	5.0
July 25 and 27	Basin east of station 4.	Elk grass (*Carex geyeri*), *C. umbellata brevirostris*, and short-awned brome grass (*Bromus marginatus*).	50	do	8.6	19.3	15–20° E.	14	74	5.3
July 27	North of station 5	*Festuca viridula*, *Bromus marginatus*, *Trisetum spicatum*, and *Melica bella*.	15	do	9.2	26.4	5° SW.	24	170	7.1
	Sturgill range.									
July 28	Sheep bed ground	*Carex umbellata brevirostris*, wild tansy (*Achillea millefolium lanulosa*), *Stipa minor*, and western needle grass (*S. occidentalis*).	(a)	Deep clay loam	21.2	34.7	1–2° SW.	17	401	23.6
July 29 and 30	Northeast of bed ground.	*Festuca viridula*, big bunchgrass (*Agropyron spicatum*), and small bluegrass (*Poa sandbergii*).	40	Clay loam	9.0	22.0	3.6° SW.	12	50	4.2
July 31	Near ridge west of bed ground.	*Stipa minor*, and *Agropyron spicatum*	20	Gravelly clay loam	5.4	16.1	5° S.	14	49	3.5
August 3	On ridge west of bed ground.	*Poa sandbergii* and *Stipa minor*	10	do	8.5	17.8	Level	9	36	4.0
August 4 and 5	Slope south of bed ground.	*Festuca viridula*, *Carex geyeri*, smooth wild rye (*Elymus glaucus*), and horsemint (*Lophanthus urticifolius*).	25	Clayey loam	9.3	11.8	4–7° S.	11	36	3.3
August 8 and 9	Slope south of camp	*Festuca viridula*, *Melica bella*, and *Poa sandbergii*	40	Gravelly clay loam	11.0	18.0	5° E.	12	76	6.4
August 10	Ridge south of camp	*Agropyron spicatum*, *Stipa occidentalis*, and *Carex umbellata brevirostris*.	35	do	8.2	14.8	Level	14	57.4	4.1
August 13	At base of south slope near camp.	*Carex geyeri*, *C. umbellata brevirostris*, slender hair grass (*Deschampsia elongata*), and tufted hair grass (*D. caespitosa*).	60	Black loam	16.4	28.2	2° S.	10	113	11.3

[a] Almost denuded.

Fully four-fifths of the total seedling stand on the areas examined was composed of sedges, and of these the species locally called "sickle" sedge (*Carex umbellata brevirostris*, fig. 5), a wiry, unpalatable, early-maturing, unusually prolific plant, was most abundant. This plant has a wide local distribution and, unlike most sedges, can grow in many different situations. The fact that it matures early strongly favors its reproduction. The flower stalks were produced as early as July 10 and mature seeds were found by August 5. Not only does it mature so early that grazing does not materially affect the seed-crop production, but it has strong seed habitats, and to a considerable extent it is perpetuated by rootstocks. The other forage seedlings observed were, in the order of their abundance, little needle grass (*Stipa minor*), brome grass (*Bromus marginatus*), hair grass (*Deschampsia elongata*), butterweed (*Senecio triangularis*), and mountain dandelion (*Agoseris glauca*). Table 1 shows that these particular species had a fairly high germination per cent.

PROGRESS OF THE NATURAL RESEEDING EXPERIMENTS.

Each of the three areas reserved for the natural reseeding experiments supported a band of sheep during the last fifth of the summer grazing period. The studies had showed that practically one-fifth of the summer grazing season still remained after the majority of the most valuable forage plants had matured their seeds—approximately on September 1.

Two of the areas are west of Bear Creek on the old Standley and Sturgill ranges, and the third, the East Bear Creek range, is near the head of East Bear Creek, a tributary of main Bear Creek.

The area on the Standley range is the most destructively overgrazed of those selected for study. And even though the range has not been completely denuded, the original vegetation is extremely sparse in some situations, and the effect of continued overgrazing has so weakened individual plants that they do not produce the normal amount of forage.

The Standley and Sturgill range areas are similar in their general topography, and neither is especially irregular. On the former, however, the greater part of the area slopes gently to the west, while on the latter are several exposures of varying degrees of incline. The character of the vegetation is similar on both these ranges. The plants that furnish the bulk of the range forage are distinctly herbaceous and consist primarily of grasses, sedges, and rushes, with here and there, though mostly in the moister habitats, a scattered to a very dense stand of nongrass-like species and comparatively little shrubby growth. Fully six-tenths of the entire forage crop on these areas is furnished by grasses, about thirty species in all, of which the

FIG. 5.—Sickle sedge (*Carex umbellata brevirostris*), showing offshoots from the rootstocks and flower stalks with fruit in the process of development. Natural size.

nutritious mountain bunchgrass supplies at least half, or nearly one-third of all.

The area on East Bear Creek is quite different from the Standley and Sturgill areas. This range is a long narrow strip of unusually rough country with an altitude of from 1,700 to 2,400 meters (5,500 to 7,800 feet). Practically the entire reserved portion slopes steeply to the west. Up to an altitude of 2,000 meters (6,500 feet), to which the Canadian life zone extends, the range has been burned over, with the usual result of a succession of shrubs, notably fire willow. On this portion of the range, then, the browsing plants are naturally of first importance. A number of herbaceous weeds have also supplanted the original vegetation, and of these fireweed predominates; their abundance makes them quite as important as the grasses, if not more so. Where the Hudsonian zone begins the timber is more sparse and fires have been less destructive. Here mountain bunchgrass again predominates, and the grasses furnish the main part of the forage.

There was no great difference in the time at which the reserved areas were ready for grazing. The East Bear Creek range was the first to mature its seed crop. On the lower part of this area, extending to an altitude of 2,000 meters (6,500 feet), the seed crop was matured by August 20; yet on the portion above, on the mountain bunchgrass range, the seeds were not fully matured until nearly a week later. Seeds were matured next on the area on Standley range, which was ready for grazing on August 27. On the Sturgill range tract the time of maturity was latest and most varied. On the south and west slopes the seeds were mostly matured by August 25, but on the north and east exposures there was a delay of seven to ten days.

Since there was an abundance of feed elsewhere, the sheep bands were not turned on the protected areas until the latter part of the first week in September. In accordance with the observations made in 1907 the forage crop at this time in the season, particularly mountain bunchgrass, was grazed with much relish. It can not be said, however, that mountain bunchgrass and the other valuable grazing plants were eaten with the same gusto after seed maturity as they were when the flower stalks were young and tender. This is shown by the fact that the first time a band passed over a matured range only about half of the forage supply was grazed off, and only when it was grazed a second or third time was the crop well consumed; whereas ranges of similar vegetation, grazed a month earlier, were in most cases consumed when the stock had passed over the area a single time. A comparison of the grazed portions of the closed areas with the adjoining tracts which were eaten off a month earlier, before the seeds had begun to ripen and when the forage was much more suc-

culent and tender, showed that on the closed areas the naked flower stalks were still standing, rising from leafless tufts of bunchgrass, and that they were absent from the ranges grazed earlier.

RESULTS TO STOCK AND RANGE.

The experiment has been carried successfully to the point where a good seeding has been secured without the waste of any of the season's crop of forage. How well the seeds will germinate and what improvement there will be in the stand of forage will not be known until another season has passed.

Some of the stockmen maintained that the air-cured or matured forage would furnish an inferior, unpalatable feed and that this would not only be a wasting of the season's crop, but would induce the stockmen to keep their bands in the mountains later than usual; and this in turn, owing to the lack of nutritious and palatable feed, would result in a considerable loss in the weight of the lambs just before they are placed upon the market. It was further contended that this unpalatability of the forage would be sure to get the stock to rambling around and to trailing, and thereby to wear out the range. The actual results were quite contrary to these contentions. In the first place, the leaf blades are not air-dried for a considerable period after seed maturity, since only the terminal portions are cured. As evidence of the palatability and nutritiousness of mountain bunchgrass and of practically all the valuable forage plants, especially the grasses, they were closely grazed from all the protected areas and the stock left the mountains in excellent condition. With an area of choice forage reserved for late grazing there is the assurance that the season can be completed with an abundance of nutritive and fattening feed, instead of a resort to ranges that were partly grazed earlier in the season or to those on the lower levels, where the forage has been dry and unpalatable for considerable time.

A protective grazing system should be continued as many seasons as may be necessary so to establish the seedling plants that moderate grazing will not result in serious loss; or if the natural seedling stand is not sufficiently dense from a single year's protection, a supplementary artificial seeding may bring about the desired result.

Approved:

JAMES WILSON,

Secretary of Agriculture.

WASHINGTON, D. C., *July 7, 1909.*

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